2000 c.c. It is possible, however, that nitrogen might be oxidised, and thus not manifest itself under the above tests. In another experiment the water of combustion was examined for acidity, but without definite indications of nitric acid. The slight reddening observed appeared to be rather that due to carbonic acid, some of which, it must be remembered, would be dissolved in the water. These and other matters demand further attention.

The somewhat complicated glass blowing required for the combustion apparatus has all been done at home by my assistant, Mr. Gordon, on whom has also fallen most of the rather tedious work connected with the evacuation of globes and other apparatus, and with the preparation of the gases.

II. "On the Wave-length of the Principal Line in the Spectrum of the Aurora." By WILLIAM HUGGINS, D.C.L., LL.D., F.R.S. Received February 19, 1889.

Notwithstanding the large number of determinations by different observers, since Ångström in 1867, of the wave-length of the principal (and frequently the only) line in the spectrum of the Aurora, this value has not yet been accepted as definitely fixed with the degree of accuracy which is required for a final inquiry into its chemical origin. The uncertainty within rather wide limits, which seems still to obtain, has arisen mainly from the circumstance that in nearly all cases the observations have been made with a small direct-vision spectroscope, and under conditions which do not admit of an accurate determination of the value sought for. About half the number of some twenty-four observers agree pretty well, but among the results given by the others the differences are very large in relation to the accuracy which is required, though they are not greater, perhaps, than was to be expected from the circumstances under which the observations were made.

I think it is very desirable, therefore, that I should put on record some observations of the spectrum of the Aurora which I made in the year 1874, but which up to the present time have remained unpublished. These observations were made with a powerful spectroscope, and under conditions which enabled me to determine the wave-length of the principal line within narrow limits of error. The spectroscope was made by Sir Howard Grubb on the automatic principle of his father, Mr. Thomas Grubb. It is furnished with two "Grubb" compound prisms; each has 5 square inches of base, and gives nearly twice the dispersion of a single prism of 60°, namely, about 9° 6′ from A to H.

The object-glasses of the collimator and telescope are 1·25 inch in

diameter. The definition is very good. Though the automatic arrangement works well, I always take the precaution to measure only small differences of position of the line to be determined from lines near it, the wave-lengths of which are known.

The observations were made on February 4, 1874. There was a brilliant Aurora, showing a whitish light; a direct-vision spectroscope resolved this light into a brilliant line in the yellow and a faint continuous spectrum.

The "Grubb" spectroscope was directed from the window of the observatory upon the brightest part of the Aurora. In the first instance, an estimation by eye was made of the position of the bright line by comparing it in the instrument with the spectrum of a spirit lamp. The bright line was seen to fall on the more refrangible side of the line for which Watts gives the wave-length 5582,* Ångström and Thalén 5583,† by from one-fifth to one-fourth of the distance of this line from the beginning of the band. If we take one-fourth, we have λ 5569·6; one-fifth gives λ 5572·3. The mean of these values gives for the

Aurora line λ 5570·9 ..... (1).

The cross-wires of the spectroscope were then brought upon the line, and the reading 3476 showed the line to fall about midway between two strong lines in the spectrum of tin, λ 5564 and λ 5587 respectively, according to my measures.‡ The position of the cross was then compared directly with those lines in the spectrum of an induction spark taken between electrodes of tin. The further details of this comparison are not given in my note-book, but the result only, which placed the

Aurora line at λ 5571 ..... (2).

Consulting my map of the chemical elements, I found that there was a line of tellurium very near this place, namely, at λ 5575, I therefore brought the spark from tellurium before the slit, when the cross appeared on the more refrangible side of the tellurium line. The measure of the distance of the cross from this line came out equal to λ 0003. The place given in my paper for this line of tellurium is 5575. Thalén gives for the same line 5574·1.§ If we take the mean of these values and deduct 0003, we get for

The line of the Aurora λ 5571·5 ..... (3).

There are strong lines of iron very near this position in the

* 'Phil. Mag.,' vol. 41, 1871, p. 14.

† "Spectres des Métalloïdes," 'Nov. Act. Soc. Sci. Upsal.,' vol. 9, 1875 (p. 29).

‡ "Spectra of the Chemical Elements," 'Phil. Trans.,' 1864, p. 139.

§ 'Brit. Assoc. Rep.,' 1885, p. 292.

spectrum, and I made use of these also for a further determination of the place of the Aurora line. The cross, after having been placed upon the line of the Aurora, was confronted with these lines in the spectrum of iron.

The condensed account in my note-book does not give further particulars of this comparison, but states only that the place of the

Aurora line came out λ 5571·5 ..... (4).

Summing up these determinations we have—

(1)	Eye-estimation	λ 5570·9
(2)	From tin	5571·0
(3)	From tellurium	5571·5
(4)	From iron	5571·5

From these values I think that we are justified in taking for the Aurora line, as a position very near the truth,

λ 5571 $\pm$ 0·5 ..... (5).

Among the numerous determinations of other observers, those of Professor H. C. Vogel in 1872* seem to me to have great weight. A direct-vision spectroscope with a set of five prisms was used. The reduction of the readings of the micrometer into wave-lengths was based upon the repeated measures of 100 lines of the solar spectrum.

The screw had been thoroughly examined. After each observation of the Aurora line, readings were taken of the lines of sodium or of hydrogen. The observations extended over four nights. On three nights four separate readings were obtained; on the fourth night two only. Vogel gives as the mean result of the fourteen observations,

Aurora line λ 5571·3 $\pm$ 0·92 ..... (6).

Perhaps I should state that I find, from a remark in my note-book, that at the time of my observations in 1874 I was not aware of Vogel's results, and I could not, therefore, have been biassed in any way by them.

The recent observations on the spectrum of the Aurora by Gyllenskiöld, at Cap Thordsen, in 1882, deserve special mention.† With a Hoffmann spectroscope, furnished with a scale, he obtained at Cap Thordsen in 1882 a mean result of λ 5568 $\pm$ 1·6; later, in 1884, at Upsala, with a Wrede spectroscope furnished with a micrometer screw, a mean value for the Aurora line, λ 5569 $\pm$ 6·2.‡ Gyllenskiöld

* 'Leipzig Math. Phys. Berichte,' vol. 22, p. 285.

† 'Observations faites au Cap Thordsen, Spitzberg, par l'Expédition Suédoise,' vol. 2, I:—Aurores Boréales, par Carlheim-Gyllenskiöld. Stockholm, 1886.

‡ *Ibid.*, p. 166.

discusses in detail nearly all the recorded observations of the spectrum of the Aurora from 1867 to 1882, and then brings them together in a table, with such probable errors as the original statements of the observers enabled him to assign to them. I think it is desirable to give that part of his list which contains the observations of the brightest line :—

1867.	Ångström	Upsal.....	λ 5567 ± 1·0
1868.	Struve.....	Poulkowa.....	5552 ± 14·9
	Lemström	Tromsœ.....	5659 ± 14·0
1869.	Peirce	États Unis.....	5565 ± 10·8
1870.	Proctor	.....	5595 ± 25·0
1871.	Smyth.....	Édimbourg.....	5579 ± 9·5
	Lindsay	Aberdeen	5680 ± 50·0
	Barker.....	New Haven	5594 ± 13·0
1872.	Vogel	Kiel	5571 ± 0·9
	Denza	Moncalieri.....	5568 ± 11·9
	Donati.....	Florence	5569 ± 10·0
	Oettingen	Dorpat	5548 ± 30·0
	Respighi	Rome.....	5574 ± 10·0
	Wijkander	Spitzberg	5572 ± 1·0
1873.	Backhouse	Sunderland	5660 ± 10·0
	Barker.....	New Haven	5569 ± 13·9
	Lemström	Enare	5569 ± 0·5
1874.	Backhouse	Sunderland	5570 ± 10·0
	Maclear.....	"Challenger"	5522 ± 37·1
1879.	Nordenskiöld	Pitlekaïe.....	5563 ± 10·0
1880.	Copeland.....	Dunecht	5572 ± 2·0
1882.	Gyllenskiöld	Cap Thordsen	5568 ± 1·6
1884.	„	Upsal.....	5569 ± 6·2

Gyllenskiöld then calculates by the method of least squares the mean value of all the determinations, and finds the following result :—*

Mean value of the 23 observations, λ 5570·0 ± 0·88 ..... (7).

The recent measures by C. C. Krafft,† depart largely from Gyllenskiöld's mean value. Krafft found on

1882, November 2	λ 5595
„ „ 11	5586

and measures with the same instrument made by Schroeter on November 17th, gave λ 5587.

* *Ibid.*, p. 169.

† 'Beobachtungs-Ergebnisse der Norwegischen Polarstation,' &c. A. S. Steen. Christiania, 1888.

Now, though Ångström's original value λ 5567 may not be quite accurate, his observation fixed a limit towards the red beyond which the Aurora line cannot lie. Ångström says, "sa lumière était presque monochromatique, et consistait d'une seule raie brillante située à gauche" (on the more refrangible side) "du groupe connu des raies du calcium."* The position of the most refrangible line of this calcium-group is accurately known; according to†

Kirchhoff	λ 5580·9
Thalén	5580·9
Huggins	5581·0

It is certain, therefore, from Ångström's first observation in 1867 alone, that the Aurora line lies well on the more refrangible side of wave-length 5580. This limit towards the red was confirmed afterwards by Ångström himself; he says later that the yellow line falls almost midway between the second and third line of the shaded carbon group.‡ The positions of these lines of comparison are, according to Ångström and Thalén, λ 5538 and λ 5583.§

It follows that Krafft's values, λ 5586, λ 5587, and λ 5595, must be from some cause inaccurate. A possible explanation may be found in the small number of solar lines employed by Krafft for the reduction of the measures into wave-lengths. The curve was drawn through the six Fraunhofer lines B, C, *a*, D, E, and *b*. There was no control for the curve between D and E, and a very small deviation of the curve from its true position here would be sufficient to account for the position of less refrangibility of from λ 0016 to λ 0024, which his measures give for the Aurora line.

It should be stated that Krafft expresses regret that more attention could not be given to the spectroscopic observations. He says:— "Leider gestatteten die obligatorischen Beobachtungen nicht, den spectroscopischen Untersuchungen die gehörige Aufmerksamkeit angedeihen zu lassen. . . . . Ich glaubte ausserdem diese Messungen um so mehr auslassen zu können, als der Platz der gewöhnlichen Nordlichtlinie oft und sehr genau bestimmt ist."

To sum up, we have the following values for the principal line of the Aurora:—

(6)	1872, Vogel	λ 5571·3 ± 0·92
(5)	1874, Huggins	5571·0 ± 0·5
(7)	Gyllenskiöld's mean of 23 observers from 1867 to 1884	5570·0 ± 0·88

* 'Spectre Solaire,' Upsal, 1868, p. 42.
† 'Brit. Assoc. Rep.,' 1884, p. 372.
‡ 'Nature,' vol. 10, p. 211.
§ 'Acta Upsal.,' vol. 9, 1875 (p. 29).

These values agree closely, and fix within very narrow limits, the position in the spectrum, where we have to seek the chemical origin of the line.

Gyllenskiöld, from his observations of the changes which occur in the spectrum of the Aurora, comes to the conclusion that: "le spectre de l'Aurore boréale résulte de la superposition de plusieurs spectres différents," and that "la raie principale forme un de ces spectres élémentaires; elle apparait très souvent seule." A similar view was taken many years ago by Ångström* and by Vogel.†

[After consideration, I think that I ought to point out that Mr. Lockyer's recent statement‡ that:—"The characteristic line of the aurora is the remnant of the brightest manganese fluting at 558," is clearly inadmissible, considering the evidence we have of the position of this line.

In support of this statement Mr. Lockyer says:—"Ångström gave the wave-length of the line as 5567, and since then many observers have given the same wave-length for it, but probably without making independent determinations. Piazzi Smyth, however, gives it as 558, which agrees exactly with the bright edge of the manganese fluting. R. H. Proctor also gives the line as a little less refrangible than Ångström's determination. He says:—'My own measures give me a wave-length very slightly greater than those of Winlock and Ångström' ('Nature,' vol. 3, p. 468)."

By reference to Gyllenskiöld's table it will be seen that the probable errors of the determinations by Piazzi Smyth and Proctor, $5579 \pm 9{\cdot}5$ and $5595 \pm 25{\cdot}0$ respectively,§ are too large to entitle these measures to special weight.

Mr. Lockyer says further:—"Gyllenskiöld's measures with the Wrede spectroscope also give 5580 as the wave-length of the characteristic line. I feel justified, therefore, in disregarding the difference between the wave-length of the edge of the manganese fluting and the generally accepted wave-length of the aurora line."

Gyllenskiöld's single measure of 5580, on which Mr. Lockyer relies, differs widely from the values which Gyllenskiöld himself assigns to this line, namely, from observations at Cape Thordsen in 1882, $\lambda\ 5568 \pm 1{\cdot}6$, and from observations at Upsala in 1884, with the Wrede spectroscope, $\lambda\ 5569 \pm 6{\cdot}2$.

Speaking of Krafft's observations, Mr. Lockyer says:‖—"The wave-

* 'Nature,' vol. 10, p. 210.

† 'Leipzig, Math. Phys. Berichte,' vol. 23, p. 298.

‡ 'Roy. Soc. Proc.,' vol. 45 (1889), p. 234.

§ Gyllenskiöld's statement of Proctor's value is based on 'Nature,' vol. 3, p. 347 and p. 68.

‖ 'Roy. Soc. Proc.,' vol. 45 (1889), p. 241.

lengths obtained for the aurora line were 5595, 5586, and 5587. Unlike most observations, these place the aurora line on the less refrangible side of the manganese fluting. Hence, we have an additional reason for neglecting the difference between the wave-length of the brightest edge of the manganese fluting, and the commonly accepted wave-length of the aurora line, as given by Ångström. . . . . These observations are the latest which have been published, and were obviously made with a full knowledge of all previous work, so that their importance must be strongly insisted upon."

I have already pointed out that Krafft's measures were not made under circumstances which assured to them a high degree of accuracy; and Krafft's own words, which I have quoted, disclaim expressly any special attempt on his part to redetermine the position of the principal line with a higher degree of accuracy than the observers who preceded him.—March 4.]

III. "On the Cranial Nerves of Elasmobranch Fishes. Preliminary Communication." By J. C. EWART, M.D., Regius Professor of Natural History, University of Edinburgh. Communicated by Professor B. SANDERSON, F.R.S. Received February 22, 1889.

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